Surgeon General of the United States Navy.

"Self-treatment of venereal disease is not permitted in the Navy. All cases must be treated under the direction of a medical officer. No other method would be tolerated."—*Surgeon General of the Navy.*

SOME ASPECTS OF MALARIA CONTROL THROUGH MOSQUITO ERADICATION.

By C. W. Metz, Special Investigator, United States Public Health Service.

From a sanitary standpoint one of the most striking accompaniments of the recent military activities in this country has been the institution of malaria-control operations on a scale probably never before attempted except on the Isthmus of Panama during the construction of the canal. These operations have been intended primarily to prevent the introduction and spread of malaria in the various newly established cantonments, munition factories, and other places of military importance, but they of necessity also embraced large areas of civilian territory and have affected a vast rural and urban population. In connection with this campaign practically all known anti-malaria measures have been used, including quininization, screening, etc., but the great bulk of the work has been devoted to mosquito eradication. Within the actual military areas themselves this work has been conducted principally by the Army Medical Corps. In the surrounding zones—constituting by far the larger and more menacing territory—however, it has fallen to the lot of the United States Public Health Service, aided by such local health organizations as happened to be available in the respective localities.

To meet the requirements of the sudden exigency, the Public Health Service force engaged in malaria control was, of course, rapidly enlarged and put immediately to work, without the formality of complete standardization of methods and organization that might have been effected had more time been available.[1] As a result the conduct of operations in the various extra-cantoment zones, although based upon the same general principles throughout, has differed somewhat from place to place, so that it is difficult to include all of the methods of procedure in one general statement. Consequently, the following account will be based largely upon the operations with which the writer is personally familiar, and will not attempt to cover all of the modifications of procedure to be found in different regions.

It should also be made clear at this point that the present communication makes no pretence at being a complete discourse on mosquito

[1] It might be added, parenthetically, that a great deal of good has come from this necessity. With many men working along the same lines in differet parts of the country, and each presented with his own local problems, the result has been that numerous innovations, ingenious methods, more efficient tools, etc., have been introduced, greatly to the benefit of the operations as a whole.

control. Details of many phases are entirely omitted, as these are already well known and are accessible in published accounts.

In general the principles of mosquito control used in the extra-cantonment sanitation have been those used so effectively in the Canal Zone, and described by Le Prince and Orenstein (1916). They consist primarily of drainage and oiling—drainage where the water can be disposed of, and oiling where it must remain. Both of these methods are aimed, of course, at the *Anopheles* larvæ. Little, if any, attempt has been made to combat the adult mosquitoes, since the other methods are found much more effective.

Knowing, with a fair degree of certainity, that malaria transmission is effected only by mosquitoes of the genus *Anopheles,* and knowing the approximate range of flight of these insects, it remains to eliminate them from a zone around each camp corresponding with the range of flight, namely, 1 to 2 miles. The exact extent of the zone varies somewhat in different places, depending upon the amount of breeding and the exigencies of the work, but as a rule it is intended to cover all prolific breeding areas within 2 miles of habitations occupied by the people to be protected. This includes, in typical extra-cantonment work, the zone around the cantonment proper and similar zones around the rifle range, remount station, aviation fields, and other auxiliary military areas.

In the region east of the Mississippi, which is the region of primary interest from the present standpoint, there are three species of mosquitoes to be considered as vectors of malaria, *Anopheles quadrimaculatus, Anopheles punctipennis,* and *Anopheles crucians.* These species differ strikingly from one another in appearance and in habits, and probably also in their importance as agents of malaria transmission. Regarding the latter point, however, too little is known at the present time to allow of much discrimination, and as a rule all *Anopheles* are treated alike in control operations. It is well, nevertheless, to keep in mind the principal characteristics of the different species and also the main questions that remain unsettled. This will lead to more intelligent field work and allow more information to be obtained regarding the uncertain points. The main features of interest are as follows:

Anopheles quadrimaculatus.—This species may be distinguished from either of the other two by its relatively hyaline wings, with their four dot-like aggregates of scales. Its larval habits are relatively exact, with a restricted range of adaptability. Like other *Anopheles* it breeds in natural waters in preference to artificial containers, eaves troughs, etc., although it will occasionally, when hard pressed, breed sparingly in these, too. In general it chooses quiet water, either ponds, swamps, pools, puddles, lakes, or lagoons. Apparently it is very seldom found in running water, although evidence on this

point is not entirely conclusive. It is perhaps the most fastidious of the three species in regard to the character of the water in which it breeds. A small amount of sewage will effectually prevent breeding, as will also relatively small amounts of chemical or other contamination.

As a vector of malaria *quadrimaculatus* undoubtedly heads the present list; it transmits the malaria plasmodia readily, as has been shown both by practical observations and by laboratory experiments. Not only does it appear to be physiologically well adapted to this rôle, but it has habits of feeding that make it particularly effective. It seems to have an especial fondness for the society of man, and will enter houses to feed more readily than will either of the other two species. Whether it actually prefers human blood to that of domestic animals is not known, but apparently its fondness for man is almost or quite as great as for domestic animals, whereas the other two species exhibit a definite preference for the latter.

Anopheles punctipennis.—In point of numbers and general distribution this species should rank first. It is easily distinguished from the other two by the marginal white or yellowish spot on the heavily scaled wings and by the slender thorax with a pale longitudinal stripe along the dorsum. Its larvæ appear to be indistinguishable from those of *quadrimaculatus*. Its choice of a breeding place may include any of those mentioned for *quadrimaculatus*, and in addition streams or ditches of running water, provided, of course, the flow is not so rapid as to destroy the larvæ or prevent breeding. Apparently *punctipennis* is also somewhat less fastidious about the character of the water in which it breeds, as it seems able to stand more contamination than *quadrimaculatus*. On this point, however, there is little exact evidence.

Owing, apparently, to the different habits of the adults, *punctipennis* is generally thought to be less effective as a malaria vector than *quadrimaculatus*. It is known to harbor the malaria plasmodia and allow typical growth and development of the parasites, and also to transmit malaria under laboratory conditions (Mitzmain, 1916), but observations by several competent persons in various localities have led to the impression that *in nature* it is relatively unimportant as a vector of malaria.[1]

The importance from a practical standpoint of determining the rôle played by *punctipennis* in malaria transmission may be appreciated by considering the immense amount of money that is being spent on the eradication of *punctipennis* breeding places in running water alone, practically all of which could be saved if it were certain that the species is not a frequent vector of malaria.

[1] See recent summary by Asst. Surg. Gen. H. R. Carter, Reprint No. 464 from Public Health Reports, 1918.

Anopheles crucians.—This species is generally less common than the other two and is found in the most restricted localities, although it may be extremely abundant in suitable places. It is readily distinguished from either of the others by the wing markings, among which may be mentioned especially the apical yellowish or white spot and the three dark bands on the sixth vein. The larvæ of *crucians* in the later stages may sometimes be distinguished from those of the two others by the palmate dorsal hairs. The distinction may be appreciated by reference to a good figure, such as that in plate 84 of Howard, Dyar, and Knab's "Mosquitoes of North and Central America." It will be observed that the larva of *punctipennis* or *quadrimaculatus* has a pair of palmate tufts of hair on the dorsum of each of the third to seventh abdominal segments, and that all of these pairs are of practically the same size. This is characteristic of *punctipennis* and *quadrimaculatus;* but in *crucians* the first and last of those pairs are very small. In other words, *crucians* has large palmate tufts on the fourth, fifth, and sixth segments only, with small ones on the third and seventh. It should be noted that the posterior pair of tufts is frequently small in any of the species, but so far as the writer has been able to observe the distinction holds for the tufts on the third segment.[1] In breeding habits, likewise, *crucians* differs rather sharply from the other two species. Although it may sometimes be found in company with either of the latter it is often to be found in brackish waters or waters contaminated with chemicals. In such places, when the contamination is great enough to prevent the breeding of other *Anopheles, crucians* may sometimes be found in enormous numbers. The writer has recently been studying one such place in which the drain from a chemical factory so contaminated the water that many aquatic organisms, including fish, were killed, and *crucians* had a clear field. In this swamp *crucians* were being produced literally by the millions, although not a single *punctipennis* or *quadrimaculatus* was obtained out of scores of larvæ and adults examined.

As a vector of malaria *crucians* is a relatively unknown quantity. Presumably it is an efficient carrier, as suggested by the prevalence of malaria in localities such as that just mentioned where the other species are uncommon and by the fact that it is known to harbor at least one of the malaria parasites (Mitzmain, 1916); but on the other hand *crucians* resembles *punctipennis* in its apparent preference for the company of domestic animals rather than that of man. This is another matter requiring further investigation.

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[1] Since the above was written it has been found that the distinction does not hold in all localities. In Florida the writer has found crucians larvæ with large palmate tufts on the third segment. Another distinction, pointed out by Howard, Dyar, and Knab, is based on the fact that *quadrimaculatus* and *punctipennis* typically have a small tuft of hairs on the second segment, making six in all, whereas *crucians* has only five. This criterion, however, is also unreliable, for the tuft on the second segment is frequently absent (as, e. g., in the specimen figured in the plate cited above).

From the foregoing it may be seen that additional evidence is greatly needed regarding certain phases of mosquito control in relation to malaria, and that until this is obtained safety demands the control of all *Anopheles*. In case a selection must be made, however, it appears advisable to control *quadrimaculatus* first by eliminating breeding in still water, especially grassy puddles and pools.

Turning now to the question of ways and means of control, the salient features may be considered under three headings: Drainage, oiling, and accessory measures.

Drainage.

In drainage we have the most reliable and most permanent control. Where there is no water in which the larvæ may develop there will be no mosquitoes, and when a place is once properly drained it will not become a nuisance again for a considerable period of time. Drainage, then, is the main reliance in mosquito control unless the effort is intended to be only a very temporary expedient. Under drainage, from the present standpoint, are included several features peculiar to mosquito control and perhaps not included under drainage as the engineer would define it. Among these may be mentioned cleaning of ditch banks, removing débris from streams, etc. Drainage may be either of the usual type, or under special circumstances the so-called "vertical drainage." These will be considered separately.

Since all of these measures are aimed at the destruction of *Anopheles* larvæ, attention should first be directed to the general conditions necessary to bring this about. The methods are simple, but upon the proper choice of methods may depend many lives and thousands of dollars.

Anopheles larvæ will not develop in a locality if—

1. The water is completely drained off; or

2. The water surface is entirely cleared of vegetation or other obstructions, the banks cleaned and cut down vertically, giving a smooth margin; and

(*a*) An abundance of suitable fish made available to keep down the larvæ; or

(*b*) A complete film of oil applied to the entire surface; or

(*c*) A swift flow of water set up to carry off the larvæ or prevent their feeding; or

3. The water is treated with an effective larvicide.

Obviously the choice between these methods will vary according to the nature of the place and the degree of permanence desired for the results.

Surface drainage.—In practice one may find himself confronted with any one or all of the following types of areas requiring drainage:

Temporary puddles, stagnant ditches, borrow pits, old wells, cisterns, ponds, lakes, swamps, marshes, streams, lagoons, and bayous. Of these the temporary puddles, unless there are several of them in a locality that may be ditched without much difficulty, can probably be controlled best by the use of oil. Roadside ditches—excellent breeding places as a rule—can usually be ditched without much difficulty and eliminated at once. (See reference to ditching machine at the end of this paper.) Borrow pits are treated according to circumstances. Many are too deep to be drained and must be oiled. Not infrequently they are deep enough down in the sterile earth to be practically devoid of aquatic life and can be ignored, but in this case frequent careful inspections should be made to see that they remain free from larvæ. Old wells, cisterns, and the like may often be filled to advantage, or oiled, or treated with chemicals as described later; it is seldom advisable to attempt drainage. It is when we come to ponds, lakes, and swamps that the real problems arise, and it is best perhaps to consider these three together. Since the difference between lakes and ponds is only one of degree, and since swamps may include either or both of the other two, it is obvious that in actual practice little distinction can be made that would involve different methods of drainage. It is more important to classify such areas according to the sources of water, for in this case the distinctions correlate with modes of treatment. For instance, one pond or swamp may be caused by the accumulation of rain water and may fluctuate greatly with the seasons, another may be simply a basin in the channel of a sluggish stream, while a third may be fed from springs and may be bordered by a seepage outcrop. In the first of these, the rain-water swamp, it is merely necessary to provide a small channel to carry off the surplus water left after the main flood waters have passed. As a rule one or two ditches will suffice. In the second case the situation is more difficult, for the water supply is continuous and fluctuating. The swamp will vary in size with high and low water in the stream, and a drainage operation of considerable magnitude may be required to eliminate it. Before determining the method of procedure in such a case it is well to consider the fundamental requirements of mosquito control with a view to selecting the most economical and effective method. In case drainage is decided upon it will probably take the form of channeling the stream below the swamp to lower the water and increase the flow.

Otherwise a combination of clearing[1] and oiling will probably prove most effective. The third case mentioned—that of a swamp

[1] Clearing the vegetation from a swamp does not require cutting down the trees, except in very unusual circumstances. There is little support for the popular impression that sunlight will eliminate larvæ. If the water must be oiled after clearing, it may as well be oiled in the shade. This will save the trees and the expense of cutting them, will provide more comfort for the oilers, and will lessen the rapidity of evaporation of the oil. Also it will probably be conducive to better relations with property owners.

fed by a seepage outcrop—presents the most difficult problem of all. Here we have not only an area of standing water, probably full of vegetation, but also a series of tiny puddles in the form of hoof prints, etc., along the outcrop margin. Each of these is a potential breeding place of the worst kind. The treatment of such an area requires a special procedure, and since the proposition is one that is

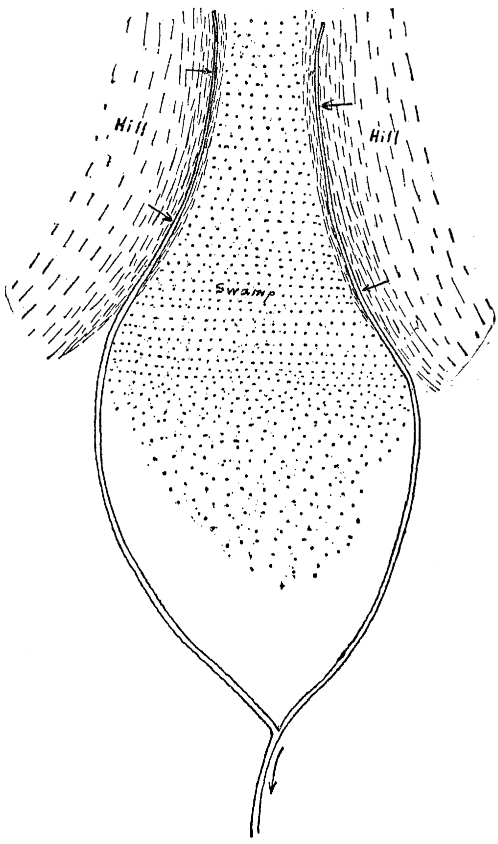

FIG. 1.—Seepage outcrop ditches.

apt to be found in most any locality it may be considered in some detail.

Treatment of seepage outcrops.—Seepage water usually appears on hillsides, etc., at the outcrop of a stratum of water-bearing sand or gravel underlain by an impervious stratum of clay, shale, or other material. The outcrop may be in the nature of more or less distinct springs, or simply a gradual oozing out through the soil. In either case it is fed by a water table below the surface, and treatment must be aimed particularly at this water table. It does not suffice to dig ditches directly away from the springs and down the hillside.

Such a method would require a separate ditch for each spot from which water is issuing, and would mean, in many cases, a series of ditches about 12 inches apart along the whole hillside. The only effectual way of collecting the water in such places is by means of ditches dug *at right angles to the flow of the seepage water*, or, in other words, across the exposed end of the water table. Such ditches

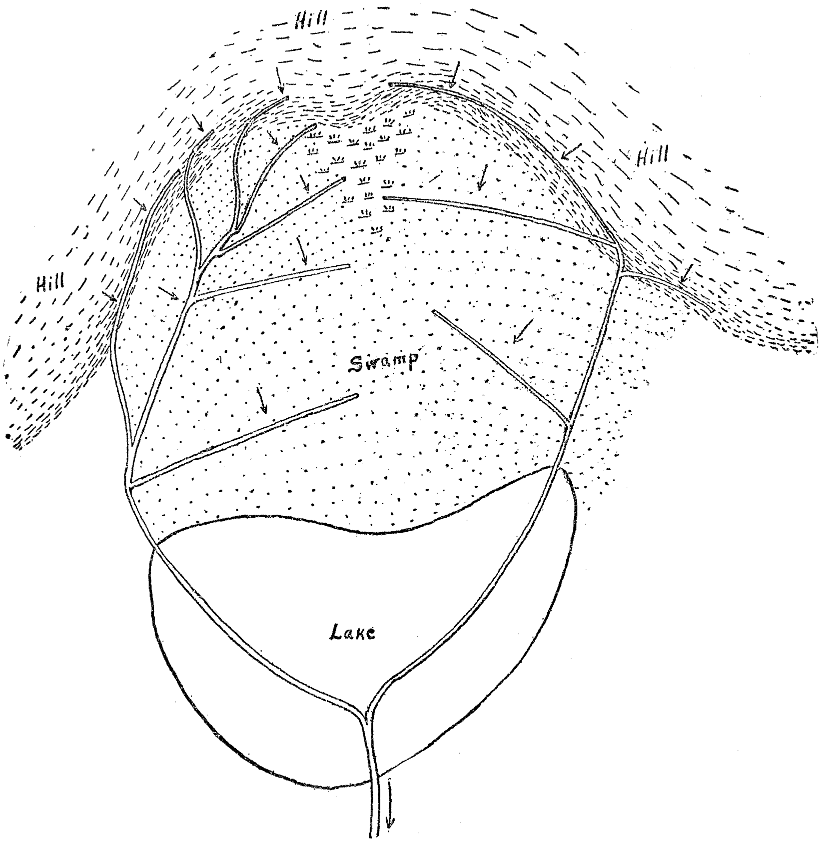

FIG. 2.—Seepage outcrop ditches.

may then be connected to one or more main ditches, if necessary, and the water carried down the hillside parallel to the seepage flow. These points are illustrated roughly in the accompanying sketches of actual swamps.

In No. 1 there was seepage on both sides of a narrow valley, the water coming out of two hills opposite one another, as shown by the arrows. As a result the bottom of the valley in this region was a typical cat-tail swamp with water from 1 inch to 2 feet in depth. Since the source was somewhat up on the hillside, it was useless to dig a ditch through the bottom of the swamp and down the valley. This would simply carry off the deep water and leave the seepy marsh as it was. Instead a deep, narrow ditch was dug along the

margin of each hill just at the upper edge of the seepage outcrop and at right angles to the flow of the seepage water. In this manner the water table was intercepted and all the water that formerly oozed out down the hillside now seeps into the ditch and is carried off. As a result the swamp, no longer fed from the hillside, has dried up.

In case No. 2 a more complicated situation is presented. Here the seepage flow is from a large U-shaped bend in a hillside, resulting in a swamp many acres in extent, with a small lake at the outer edge. The water table in this case extended clear across the swamp, but was concealed along a slight elevation running down the middle. On account of this elevation it was necessary to drain the right and left halves of the swampy area separately. As shown in the sketch a ditch was put along the toe of the hill on each side at the upper margin of the outcrop and then run off into the lake. But the water

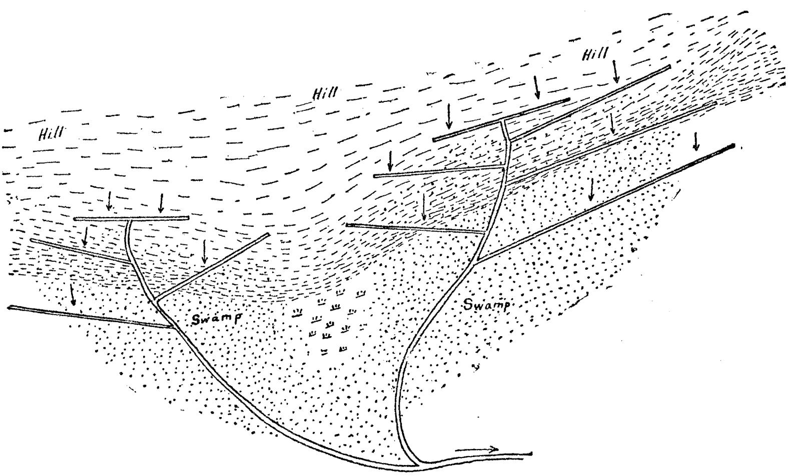

FIG. 3.—Seepage outcrop ditches.

table this time was too deep to be intercepted entirely by one ditch and it was necessary to dig additional intercepting laterals at intervals lower down. On one side five such ditches, more or less parallel to one another and at right angles to the seepage flow, were required to catch all of the water before it came to the surface.

In case No. 3 an outcrop on a relatively steep hillside is represented. Here it was necessary to dig several intercepting laterals parallel to one another and only a few feet apart in order to catch all of the flow. When this was done over the area in which the seepage water was actually coming out of the ground, the remainder of the swamp lower down the hillside became completely dry.

In each of these cases collection of the water depended upon the ditches being constructed primarily as intercepting rather than conducting ditches. In the case of swamp No. 1 the ditches happen to be intercepting and conducting at the same time; but more often

separate conducting ditches must be constructed to carry off the water after it has collected in the intercepting ditches.

With the exception of a few features like these most of the drainage work is largely a matter of running levels and managing labor. Common sense and practice are the main requisites. Here, as in the rest of the work, the habits of the mosquitoes must be kept in mind. For instance, a swiftly running ditch is better than a sluggish one; water confined in a narrow channel will run more swiftly, give less surface and be easier to oil; hence V-shaped ditches are usually preferable to wide-bottomed ones. If the ditch is large and the sides are apt to cave, they should be sloped. Sandy soil caves easily and requires relatively wide ditches. A large ditch, primarily to carry

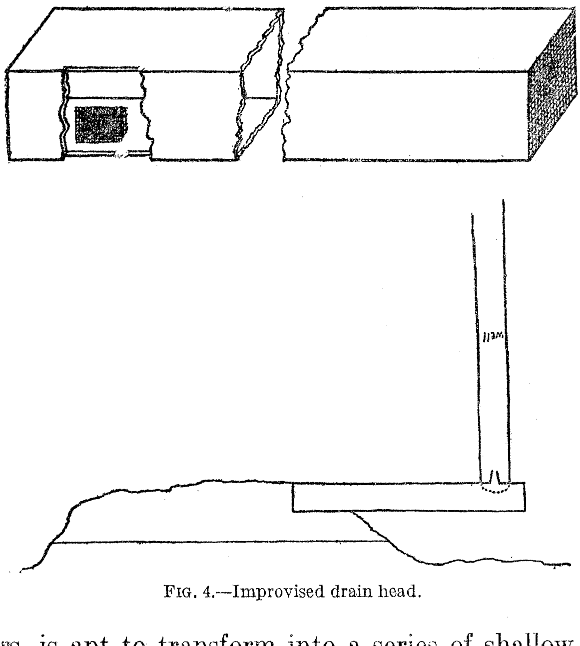

FIG. 4.—Improvised drain head.

flood waters, is apt to transform into a series of shallow puddles in the dry season. An efficient remedy for this is a small V-shaped ditch about the width of a shovel down the middle of the large ditch. It will often eliminate all of the little puddles.

Vertical drainage.—By vertical drainage is meant drainage by means of wells sunk vertically; the purpose being to conduct the water down through relatively impervious soil into water-bearing sand or gravel. Such drainage is usually advisable only where surface drainage is very difficult or expensive. No thoroughly tested and standardized method has yet been worked out for this form of drainage, but several types of drains have been used with fair success. Holes are bored near the margin of the water to be drained, and are

sunk down into an underlying water-bearing stratum. The number and size of these holes depends upon the amount of water to be drained, the rapidity with which it must be carried off and the nature of the underlying stratum. If the stratum is near the surface large, open wells may be dug or blasted out and the water carried off rapidly. If it is deep down, holes should be bored with a boring outfit and drain heads installed. Fabricated drain heads may be purchased or improvised drain heads may be made on the spot. One type used by the writer, and found to give satisfaction up to the present time, is made as follows:

An elongated, narrow, culvertlike box is constructed out of rough lumber. One end is closed tightly, and in the bottom near this end a small hole, 2 to 4 inches in diameter, is cut to come directly over the well. The hole should be only one-fourth to one-third the diameter of the well in order that the water may fall into the well without washing the sides. This box is to be laid as a pipe connecting the well with the pond and the bottom of the box should be just level with the bottom of the pond, otherwise the water will fail to flow in, or will flow too rapidly and will wash in a large amount of sediment. At best some sediment will be carried, and to reduce this to a minimum a fine screen, covered with a coarse screen is placed over the end of the box and over the hole leading into the well.

An improvement might be added to this drain head in the shape of a pipe or funnel-shaped conductor suspended vertically into the well from the hole in the box. This would tend to reduce the washing and consequent crumbling of the sides of the hole.

In practice this type of well has been used in clay soil without any lining, but in a softer soil the hole would probably require casing with tile or iron pipe to prevent its caving in.

Oiling.

Next to drainage and as an adjunct to it, oiling is the main reliance in mosquito control. The general principles of this process are well known, but a few features may bear repetition or emphasis in this connection. Since *Anopheles* seldom develop in less than 8 to 15 days, even in warm weather, it is customary to apply oil about once a week. No definite formula can be given for the oil to be used. Straight kerosene is very effective, for it spreads rapidly and will make a very thin film. But it also evaporates rapidly, and is difficult to see on the water, hence it is usually mixed with so-called crude oil [1] in parts varying from 3 : 1 to 1 : 3, depending upon the circumstances and upon the thickness of the crude oil. The most satisfactory mixture is one that is nearly black in color and slightly thicker than

[1] True crude oil is very difficult to obtain; what is usually used is fuel or black oil.

kerosene in consistency. This spreads rapidly and is easily seen on the water. In this connection it should be emphasized that an exceedingly thin film is all that is necessary. This film may be seen by the sheen it gives to the water when viewed in the proper light—a characteristic easily noted after a little practice.

Oil may be applied in various ways. In ordinary work the spray can is the main reliance. The type generally used is some form of knapsack sprayer that can be easily carried and that has an adjustable nozzle. The nozzle should be adjusted to throw a very fine spray, otherwise much of the oil will remain in globules instead of spreading out in a film.

On small streams and ditches with a fairly good current drip cans are used to advantage. Most of those in use are constructed upon the same principle, but in details they are very diverse. A discussion of several types will be found in Le Prince and Orenstein's "Mosquito Control in Pamana." As a rule each worker introduces modifications to suit his own ideas or to suit the material available. A type of can used by the writer is constructed from an ordinary 5 or 10 gallon oil can having a spout near the top. The screw cap of this spout is perforated, and a nail, packed around the basal end with waste, is inserted in the hole.[1] The can is laid on its side with the spout down so that the oil drips out along the nail. By tightening or loosening the latter the flow can be regulated down to a few drops per minute.

Another type of can, reputed to be satisfactory, is composed of an ordinary oil can to which is attached an accurately ground petcock susceptible of accurate adjustment. It is probable, however, that this can exhibits the same tendency as others toward getting clogged up with sediment to such an extent that the flow is inhibited. All types of drip cans known to the writer require inspection every few hours to insure a regular flow.

As a substitute for drip cans oil-soaked waste or bags of oil-soaked sawdust are often used. These are fastened at or near the bottom of the ditch or stream at intervals varying with the size and rate of flow. Oil oozing out of the waste or sawdust comes to the surface, spreads out into a film, and floats down stream. As in the case of drip cans the amount of oil-soaked material necessary and the intervals between the stations depend upon the volume of water, etc., and must be determined for each place separately. A little practice will indicate the proper procedure. All that is necessary is that a continuous film be produced over the entire water surface, throughout the necessary distance, and for a period of at least 12 hours once a week.

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[1] See p. 158 of Le Prince and Orenstein.

Oil-soaked sawdust, in addition to its use as a substitute for drip cans, may be sprinkled over the water surface and thus prove useful as a substitute for other methods of oiling. Its efficiency in instituting rapid control over water areas which have not been cleared of brush or débris is apt to be particularly satisfactory. The value here lies in the fact that the sawdust will often spread the oil film over the surface in spite of the weeds, sticks, grass, or whatever else would have a tendency to break up the film.

Very recently a method of oiling has been proposed by Surg. M. J. White, of the United States Public Health Service, which, when used in conjunction with oil-soaked sawdust, is intended to supplant all other methods. This is described in a circular letter issued by the United States Public Health Service, from which the following extract is taken:

"This method lays down the oil by capillarity. The wick is a piece of jute binder twine. It is common in station waste. The pepper can, also found in station waste, has a push lid which protects the oil from rain and is easily removed for subsequent filling of the can. The wick, previously oiled, is brought out the side of the can through a hole near the top made by raising the flap of the tin which also serves to prevent rain from beating in at this hole. A wire loop passed through the side of the can at two opposite points immediately below its lid is tied to a stout strip of wood or stick driven in the middle of the ditch or side of the pool at a sufficient inclination to permit the can to hang free. The can should be hung above the flood-water level and the distal end of the wick allowed to hang free in water, about 2 inches of it being submerged. The proximal end of the wick is anchored within the can by an iron nut. The can is refilled every three or four days, at which time the laborer squeezes or washes out the silt that may have accumulated on the submerged portion of the wick. The flow of the oil varies principally with the length of the wick and velocity of the water. If there are no surface obstructions such as algæ or fallen grasses, this method will supply a continuous film of oil. Fuel oil is used. If such obstructions exist they must be raked away daily so that the oil may spread. This continuous application of a thin film of oil is practiced to prevent oviposition. For larvicidal purposes the film is collected at points along the ditch by obstructing the surface with strips of wood placed across the ditch. These strips allow the water to pass beneath but arrest the surface oil. The larvæ swim away from the oiling focus and travel in the direction the oil travels. They will go upstream away from the wick if the wind bears the oil in that direction. Having determined the direction the oil will travel the wooden strips are placed from 50 to 100 feet apart. If algæ are present and rapid

work is desired a separate can is provided for each section. The oil accumulates at the wooden strips and as the larvæ, fleeing from the source of the oil, come in contact with this accumulated thick layer of oil, they receive lethal treatment. At first some of the larvæ will pass beneath the wooden strip from one section to another, but they soon succumb. In oiling a pool, cans are placed at selected points along the edges and the wind will drive the oil across. Constant oiling is thus maintained no matter the direction of the wind. A thin film of oil is larvicidal in the course of a day, and the pupæ appear to be less resistant than larvæ. Continuous oiling by capillarity is the method preferred for permanent ground pools and drainage ditches, while the sowing of oil-soaked sawdust is preferred for more or less temporary puddles, wagon tracks, hoofprints, postholes, and other small excavations. These two methods meet the requirements far better than the spray pumps and drip cans. Their use enables the laborers to devote most of their time to preventing obstructions, particularly algæ, that would interfere with the spread of the oil. They also effect substantial economy in the cost of labor, oil, and apparatus.

"The satisfactory use of oil-soaked sawdust is reported in the notes from the marine barracks at Quantico, Va., published in the Naval Sanitation Bulletin of June 14, 1918—Bulletin No. 29."

Accessory Measures.

1. *Fish control.*—Under suitable conditions fish control appears to be very effective, but it is a method that must be watched with care, for it is dependent upon the ability of the fish to obtain easy access to the larvæ, and anything that interferes with this will interfere with the control.

It goes without saying that it is also dependent upon the presence of the proper kind of fish. In the South these are usually members of the genus *Gambusia*, although other genera are said to be effective also. In case any doubts are entertained as to the best forms available for a given locality definite information may be secured from the Bureau of Fisheries.[1]

2. *Larvicides.*—At the present time larvicides are not being used to any great extent, except where they constitute the waste products of chemical factories. Probably the only one in anything like general use is niter cake, an acid by-product resembling slabs of marble in appearance. This is fairly efficient, but of limited usefulness. It is unsuited to running water or ponds that are frequently washed out by freshets. In old wells, abandoned cisterns, etc., it may be used to good advantage in case there is no danger of poisoning persons

[1] See also Radcliffe, 1915, in appended bibliography.

or domestic animals. It is said that stock will not drink water containing niter cake, but it would hardly be advisable to expose them to it unnecessarily.

The writer is at the present time experimenting with a combination oil larvicide in the form of creosote oils. This may prove to have some advantages due to the fact that it is more lethal than kerosene and that it may be effective without forming a complete film. In addition to its direct action on the larvæ, it is effective in reducing the larval food supply. The principal features of this method of control, so far as revealed by the preliminary tests, are as follows:

So-called "refined creosote" or commercial creosote, of a dark color and a consistency slightly thicker than that of kerosene, is applied in the form of a fine mist spray. The application differs essentially from that of kerosene or crude oil in that the oil is broken up into minute particles that float in the air like mist. Thus only a very small amount of material is used, as compared with the ordinary method of oiling. For this reason a small hand pump of half a gallon capacity will suffice in place of the usual 5-gallon knapsack sprayer, and a man can carry enough larvicide to last from several hours to a day or more instead of having to replenish his supply several times daily.

The style of pump used in the preliminary tests is of the automatic type that retains compression so as to provide a constant mist spray. It is the sort used for spraying disinfectants. The only essential feature is that a very fine "atomized" spray be secured—a mist that will float in the air.

Such a mist will settle over the surface of the water, into hoofprints, etc., and will float in among plants or other obstructions that may protrude above the surface, provided such obstructions do not form a complete canopy.

A remarkably small quantity of this material will kill *Anopheles* larvæ if properly applied. Apparently a film of creosote is not essential, as the lethal action is not brought about by suffocation so much as by poisoning, and the fine mist over the surface of the water suffices for this purpose.

For the treatment of small puddles, edges of streams, ponds, etc., and for handling a large territory where bodies of water are scattered and transportation is difficult this method holds considerable promise.

If the initial results stand the test of further trials on a larger scale and the method proves practicable for general use, it is believed that a substantial economy may be obtained in the lessened cost of labor, transportation, and material. The creosote costs from 20 to 30 cents per gallon in bulk, and it is estimated that 1 gallon will do the work of several gallons of oil.

Since creosote is poisonous to fish and other animals, it must be used with caution on water containing fish and on water used by stock. If a pond or stream is more than a few feet wide, fish are not affected by treatment of the edges. In small ditches with good current fish do not seem to be affected unless a large amount of oil is applied, but in small puddles even a light application is very apt to kill them. Owing to the irritating qualities of creosote, it is improbable that stock will drink water containing enough to do harm, but its use is not recommended in such cases except after careful trial.

The irritating effects of creosote are also felt by those who apply it if much is allowed to come in contact with the skin. For this reason, as well as to facilitate spreading the mist over the water, it is best, where possible, to apply it from the windward side.

In conclusion, a word may be said in regard to what might be called the social side of malaria control. The ultimate value of the present activities is going to be in direct proportion to the interest and appreciation that they evoke in the civilian communities. If the work stops with the termination of military activities, its value will have been merely ephemeral. But if, on the other hand, it proves to be the nucleus of an ever-increasing movement, its benefit to the country at large will be incalculable. Hence those conducting anti-malaria work in the field should miss no opportunity to make the work a public enterprise, understood by the public, upheld by public sentiment, and brought into the position of a permanent institution in the eyes of the public.

Useful Equipment and Supplies.

1. *Dynamite.*—With the present shortage of labor this is a valuable adjunct to ditching, either for the purpose of removing stumps from ditch lines or for digging the entire ditch. For the latter purpose the 50 or 60 per cent "straight nitroglycerine" dynamite should be used, for it only will explode by the "propagation method." Full details and demonstrations may be obtained from the leading dynamite manufacturers.

2. *Ditching machines.*—The horse and mule drawn ditching machines have been found very satisfactory for constructing ditches of less than 3-foot depth in open land. They make ideal V-shaped ditches, and in suitable localities may be operated very cheaply. In cleaning out roadside ditches they are particularly effective.

3. *The phosphate drag.*—This tool, somewhat resembling a potato fork, but much more substantial, is invaluable for cleaning out ditches or for working in marshy land that is full of roots, etc. It is so strong that it will last indefinitely even with the hardest usage, and its construction makes it superior to shovels or rakes for work

in soft ground. If not available locally, it may be obtained from wholesale hardware firms.

More specific information regarding the equipment mentioned above, the particular types found most useful, where they may be purchased, etc., may be obtained by addressing the United States Public Health Service, Washington, D. C.

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